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ABSTRACT

To determine the need for the development of a vocational education program in solar energy, an advisory committee considered opportunities for solar energy technicians and the need for the development of training programs and curricula and formulated recommendations for a program and curriculum. They concluded that the immediate need for persons skilled in installing, adjusting, maintaining, servicing, and repairing solar heating and cooling systems exists. A multi-level approach was recommended for designing, planning, and implementing a pilot curriculum. This should include short-term intensive training for current employees to upgrade skills in solar energy systems and pre-employment, post-high school one- or two-year programs to prepare two categories of technicians: (1) installers and maintenance technicians, and (2) diagnosticians. Detailed task analyses determined basic (category 1) and advanced (category 2) skills. In addition to conventional heating, ventilating, and air conditioning courses, the first-year curriculum would consist of courses involving certain materials and fabrications skills, solar radiation fundamentals, and solar heating and cooling systems. Second-year coursework for advanced training for category 2 technicians would include conventional applied science courses leading to an associate degree in that area. (YLB)

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TITLE OF PROJECT: A Study to Determine the Need for Development of a Vocational Education Program in Solar Energy Technology

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A STUDY TO DETERMINE THE NEED FOR DEVELOPMENT OF A VOCATIONAL EDUCATION PROGRAM IN SOLAR ENERGY TECHNOLOGY

Navarro College, in cooperation with the Department of Occupational Research and Technology of the Texas Education Agency, has completed a study to determine the need for the development of a vocational education program in solar energy technology. The objective of the study was to determine the need for a vocational education program in solar energy technology that will be used to train individuals in utilization of solar energy and solar energy devices as a source of power for commercial and residential construction. The accomplishment of the objective involved the following methodology: employment of a project coordinator and secretary to facilitate the study; selection of a twelve member committee from the following professional associations: the American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE); American Institute of Architects; American Society of Mechanical Engineers; Association of Home Builders; Mechanical Contractors Association; the Texas Education Agency; and solar energy specialist from industry and education.

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The advisory committee met on two separate occasions to initiate specific activities as defined by the project coordinator and to establish priorities for determining the need for the development of a vocational education program in solar technology. The specific activities were:

1. Consideration of present and future opportunities for employment in an occupation requiring training in the utilization of solar energy devices.

2. Consideration of present and future needs for the development of specific vocational education programs and curricula for the training of solar energy technicians.

3. The formulation of recommendations for a program and curriculum in solar energy technology. Special consideration was given

to the content, instructional equipment, the qualifications of instructors, and facilities to carry out an effective training program. Particular emphasis was given to the role that minority groups, the unemployed and underemployed would play in this emerging occupation.

In its initial deliberation the committee recognized four distinct applications of solar energy. These are:

Solar heating and cooling, which is the development, design, constuction, and operation of systems that utilize and/or store the radiant energy of sunlight to provide comfort control and heated water for household, industrial, or agricultural use.

Biomass conversion, which is the development, design, construction, and operation of systems and processes for the conversion of biological materials to energy sources. The technology includes such processes as the conversion of wood or other plants to alcohol, and the fermentation or decomposition of organic by-product materials to produce methane or other fuels.

Solar electric, which is the development, design, construction, and operation of systems to collect and transform the radiant energy of sunlight into electrical power. The technology includes the use of various collector (e.g., mirror concentrators) and conversion systems (e.g., photovoltaic devices) as well as solar-derived energy (e.g., wind or ocean thermal gradients).

Geothermal, which is the development, design, construction, and operation of systems and components to extract and convert the heat energy contained in geological formations to power. Geothermal resources include hot rocks, dry or wet steam, hot brines with associated methane, and magma.

The committee elected to limit the training program exclusively to all low temperature applications of radiant solar energy for space heating and cooling. It was felt that low temperature was adequate for most industrial and agricultural space heating and cooling uses based on a study made by the University of Texas which showed 45% of all energy applications in this country to be under 500° F, and 53% of the energy uses

to be no higher than 150° F.

The committee established that emphasis should be placed on the temperature gradient which has been used to define the range of applicable technologies: 300° F. This is a relatively low temperature and would exclude, for example, utility type (centralized power generation) training. The committee emphasized that the state of the arts as applied to low temperature solar is developed to the stage of practical application in the market place. Therefore, it could be designed with a minimum risk of obsolescence.

EMPLOYMENT OPPORTUNITIES

Following the decision to limit the study to low temperature space heating and cooling, the committee considered the vocational employment opportunity for individuals in this field. It recognized that ultimately the extent of the use of solar energy technology will depend on market acceptance of solar energy equipment. Nevertheless, there was acknowledgement that a substantial national commitment has been made by the U. S. Congress to increase use of solar. Such a commitment coupled with the evidence of rising fossil fuel costs lead to the conclusion that need will exist for skilled workers and technicians even though the extent of the need is as yet undefined.

Although the actual need for persons in these areas at the present time is undefined, it was the consensus of the committee that an indepth

study needed to be conducted. This study should include a market analysis to determine projected need for trained personnel in the next five years, and a comprehensive task analysis to define precisely the skills that are required of a technician in this field.

TRAINING OPPORTUNITIES

The second consideration of the advisory committee was the need for the development of a specific vocational education program for training individuals to install, adjust, maintain, service, and repair solar energy systems.

The committee noted that too often in the past, education has not been able to supply, within reasonable periods of time, a trained labor force for new and emerging technologies. It observed that frequently education continues to produce trainees for particular occupations long after the personnel needs have been satisfied. The committee, therefore, concluded that the role of education is to interact to a greater extent with industry and to become more aware of the labor market so that proper synchronization between supply and demand can be achieved.

The committee concurred that solar has a very definite role as an alternative source of energy in the future of the United States. The role of the sun as a direct source of energy is in its emerging stages, but it can make a significant impact on our energy shortages in the next ten years if conditions are present to bring it into the mainstream

of our energy resources. A paramount factor in the success of solar heating and cooling as an alternative energy source is trained manpower.

The committee concluded that if implementation of solar energy is to be achieved, a skilled pool of workers must be trained to install, maintain, and service solar devices. This is an initial step, in view of the developed state of the arts, toward public acceptance which is mandatory for success of this emerging industry.

TRAINING RECOMMENDATIONS

The committee recommended that immediate steps be taken to design, plan, and implement a pilot solar energy vocational training program that will include the following considerations:

1. Short-term, intensive, and part-time training must be designed to enable current employees to develop the skills or competencies needed to install, adjust, maintain, service, and repair solar energy systems. These short-term, intensive, and part-time training programs should be designed to fill the competence gap between what the workers must be able to do and what they can do now. These courses would probably require up to 320 clock hours of theory instruction and laboratory and shop practice, although the precise length of the training programs will have to be determined after a detailed task analysis is completed.

2. A one year pre-employment post high school training, as Category I, must be designed to develop the competencies needed for installation and routine maintenance of solar energy systems. A two year advanced training program, as Category II, must be developed to train personnel as diagnosticians.

3. Emphasis should be focused on individuals trained to install and maintain equipment now available or expected to become available within the next 5-10 years in

   a. heating water
   b. space heating
   c. cooling water
   d. space cooling

4. Training programs, regardless of duration or level of complexity, should be based upon a task analysis that identifies and delineates those skills or competencies needed by men and women who want to learn to earn a living by installing, adjusting, maintaining, servicing, and repairing solar energy components and systems.

5. The Heating, Ventilating, and Air Conditioning (HVAC) Training Program currently offered by most community colleges and technical institutes may now include several courses or components that can be utilized in the training of workers in the solar energy field.

6. The immediate training requirement is for those who can install, adjust, maintain, service, and repair decentralized solar energy systems used in residences and commercial buildings to heat

water, heat space, cool water, cool space, and provide climate control in buildings.

7. Training materials adaptable to individualized, self-paced instruction should be developed in a format which would be appropriate for teaching the educationally and socially disadvantaged.

8. Fifty percent or more of the instructional program should be devoted to practical work in the laboratory and shop. Part of this practical experience could be provided through supervised cooperative training programs developed with employers.

The third consideration of the advisory committee was to make additional recommendations concerning curriculum structure and content. A question considered by the committee was whether a trainee should be required to have completed a regular HVAC training course before he/she was eligible for admission to a solar energy program. However, the committee made no definite recommendation.

The advisory committee's assessment of the need for the curriculum of a vocational program in solar energy included two categories of trained personnel:

1. The person who has the skills and knowledge to install and provide routine maintenance of solar energy systems, as Category I.

2. The person who has the skills and knowledge to adjust, service, diagnose, and repair solar energy systems, as Category II.

The education, training, and/or experience of the first category would be prerequisite to that of the second category.

GENERAL TASK ANALYSIS FOR CATEGORY I

Task analysis for a Category I trainee involved two major task areas. The areas were identifed by the committee as:

1. Installation of solar energy systems.
2. Routine maintenance of solar energy systems.

In the installation of solar energy systems, the trained person will be expected to assemble, start up, and test a delivered system, following written and verbal instructions. These instructions should include a drawing or sketch showing the location of each unit, the orientation of each unit with respect to the structure in which the system is being installed, specifications of piping, ductwork, controls, and wiring required, the start-up procedure, and tests and criteria to determine if the system is operating properly. The individual should also possess sufficient understanding of solar systems in order to resolve unanticipated problems.

Routine maintenance of solar energy systems will require that a

person be able to recognize parts of the system which should be cleaned or parts which are worn or broken and should be replaced. He or she should be able to clean, repair, or replace such parts as indicated. The Category I person should be able to follow test procedures which include stated performance criteria and then be able to take necessary corrective action for certain findings.

When difficulties are encountered in the installation or process of routine maintenance of a system, this person should be able to communicate intelligently to persons in design or to persons working in diagnosis and repair about unusual problems which cannot be solved by routine procedures.

DETAILED TASK ANALYSIS FOR CATEGORY I

The installation of solar energy systems involves tasks associated with the various components. A typical system includes a solar collector, which itself may be fixed or tracking, and may receive either focused or direct sunlight. Such collectors may use a liquid or a gas. In addition to the collector, the design includes piping, pumps, and controls for liquid systems; or ductwork, fans and controls for gas systems. A liquid system may include a storage tank, and a gas system may include an analogous storage (rocks, for example). Because solar energy designs are often arranged to supplement conventional heating and cooling systems, and may be installed in new facilities along with the conventional systems, the person who installs solar energy

devices must also be able to install conventional heating and air conditioning systems.

Conventional heating and air conditioning installation task analysis has been carried out. HVAC curricula are offered at a number of secondary schools, colleges, and technical institutes across the country. These curricula are well defined. The detailed tasks required of persons working in Category I include most of those a person could perform after completing a typical one-year HVAC program, or after he or she has had the equivalent experience in the HVAC industry. Tasks required in addition to those one could perform on the basis of the above mentioned education and/or experience include, but are not limited to, the following:

The person should be able to measure angles and use this ability to determine proper orientation of solar collectors in an installation; fabricate the supporting brackets or structure for a collector, and install the collector using them (this requires the ability to work metal, such as drill, cut, bend, and fasten); install flashing and other materials to prevent leaks around components of the collector through the supporting structure; and install proper amounts of insulation as backing for the collector, if needed. If the collectors include a tracking mechanism, linkages must also be installed.

The other components of a solar energy system which involve tasks different from the installation of conventional HVAC designs, are the piping, pumps, controls, and control wiring. These generally will involve

water with plastic, copper, or steel piping, with dielectric unions. Water storage tanks must be installed as components of the system. If it involves air instead of water, an alternate system of ductwork, fans, controls, and storage components must be installed.

The person installing a solar energy system must be able to apply insulation to pipe or ductwork effectively. He or she must be able to provide air venting or water lines and be able to test piping systems for leaks.

This person must be able to make the necessary wiring connections within the system so that when power connections are made by an electrician the system will function as designed. The person should also be able to prepare the system for startup, and then he or she must run routine operational tests to determine if the system is functional.

The process of routine maintenance is also included in Category I and involves cleaning surfaces of collectors, checking for water leaks (or air leaks for gas systems), oiling motors and other mechanical parts, replacing belts and setting proper belt tensions, charging and bleeding the system, and conducting routine checkout procedures.

GENERAL TASK ANALYSIS FOR CATEGORY II

As previously defined, Category II includes persons who, in addition to skills mentioned in Category I, are able to diagnose problems in

solar energy systems and make appropriate adjustments and repairs.

DETAILED TASK ANALYSIS FOR CATEGORY II

A diagnostician must have skills and knowledge of measurements. This includes identification and use of instruments, and interpreting the results of them to determine the cause of problems within the system. Typical instruments would include those which measure temperature, pressure, and flow rates. This person must be able to interpret the results of the measurements in terms of the normal operation of the system (based upon standard or baseline measurements for the system). Repairs might involve leaks, corrosion, contaminants, etc. Adjustments might include valves, thermostats, or tracking mechanisms. A procedure, like descaling for water systems, might be needed in which case this person would carry out that procedure.

The tasks expected for Category II technicians generally arise in two ways: complaints from the user, or a routine check-out by the installer which shows a problem the installer is unable to handle. The kinds of diagnoses required of the person in Category II mean that this person must fully understand the function of the system and the principles of its operation. In addition, the person must be able to think analytically about the system.

CURRICULUM SPECIFICATIONS

The advisory committee concluded that the curriculum required to prepare the two categories of persons needed in solar energy systems installation, maintenance, diagnosis, and repair would be a two year program. If this type of program is developed, the first year would prepare persons to install and maintain such systems and is considered Category I.

CATEGORY I: THE SOLAR ENERGY SYSTEM INSTALLER AND MAINTENANCE TECHNICIAN

The first year of the curriculum, if implemented, would consist of those conventional HVAC courses concerned with principles of refrigeration, residential and commerical air conditioning and heating systems, control theory and application, practical applications of electricity in AC and DC control and motor circuits, and methods of heat transfer. In addition to the conventional courses (or parts of courses in an HVAC program), the first year would include courses involving certain materials and fabrications skills, solar radiation fundamentals, and solar heating and cooling systems. This curriculum assumes that the student has no previous knowledge or experience with HVAC systems, materials, and fabrications, or building codes, not to mention solar aspects of the program. The curriculum might have titles as follows:

FIRST SEMESTER

Principles of Heating, Refrigeration, and Air Conditioning

Mechanisms of Heat Transfer and Storage

Applied Electricity - AC and DC Circuits

*Solar Radiation Fundamentals

*Materials and Fabrications I

SECOND SEMESTER

*Materials and Fabrications II

Commercial and Residential HVAC Systems

*Solar Heating and Cooling Systems

Control Theory and Applications

*Building Codes

These new course descriptions might read as follows:

Solar Radiation Fundamentals

This course would include the nature of solar radiation in terms of wavelength distribution (exoatmospheric and terrestrial), solar radiation distribution and direct versus diffuse radiation, solar measurement instrumentation, sources of solar radiation data, solar radiative properties of materials, fundamentals of collectors, optics, flat place and tracking collectors and performance data, photovoltaic devices.

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*These are new courses to be designed. The balance of the curriculum represents modifications of conventional HVAC Program courses.

Materials and Fabrications I

This course would teach the person to use hand tools including files, hammers, punches, chisels and impact tools, drills, reamers, thread cutters, fasteners, gripping and cutting tools, saws and wrenches. It would also include power hand tools such as drills, sabre saws, staplers, power riveters, nibblers, power saws, routers, and hand grinders. These tools would be used in applications involving ductwork flashing, collector supports, and other components of solar energy systems.

Materials and Fabrications II

This course would emphasize welding, soldering, brazing, simple electrical fabrication glazing, and tubing and piping fabrication. Included would be arc and gas welding, brazing, cutting, electrical symbols and schematics, soldering, tubing symbols and schematics, tubing components, tubing systems, soldering and bonding of copper, steel, and plastic pipe tubing systems, and gaskets and seals. These skills would be taught with applications to solar energy systems components.

Solar Heating and Cooling Systems

This course would include in-class lectures and in-lab hands-on demonstrations and operation of the following heating and cooling

systems: domestic solar water heating systems (thermosyphon, non-thermosyphon, integration with conventional hot water, auxiliary energy-gas or electric); solar space heating systems, including water heating (and water heating systems with rock or liquid storage auxiliary flat plate or concentrating); solar cooling/heating and hot water, only liquid systems (absorption cooling, hot and chilled water, gas auxiliary or "dx" cooling as auxiliary, flat plate or concentrating collectors).

Building Codes

This course would teach the basic restrictions and concerns of building codes with respect to requirements of structural, electrical, fluid components, insulation, and heat exchangers.

Persons with several years of experience installing and servicing HVAC systems would, most likely, already possess the skills taught in all the first year courses except those solar related. Such persons could upgrade their education and training by completing these or other courses in the program. The three courses such as Solar Radiation Fundamentals, Solar Heating and Cooling Systems, and Materials and Fabrication II, represent about sixty-percent of the time required for a full-time semester. Thus, they can be completed in about nine months full-time, or about eighteen months part-time.

CATEGORY II: THE SOLAR ENERGY SYSTEMS DIAGNOSTICIAN

The field service technician for solar energy systems (the person qualified to diagnose, adjust, and repair other than routine matters) would be required to take the first year program (or the quivalent experience plus the three or so courses cited) plus one more year of additional course work. The additional course work could include the following and any additional courses necessary to meet state or institutional distribution requirements if an associate in applied science degree is to be awarded:

THIRD SEMESTER

Applied Math

Applied Physics

Chemistry of Corrosive Materials

Temperature, Pressure, and Flow Transducers

Technical Elective (e.g. hydraulic systems)

FOURTH SEMESTER

Test and Measurement Instrumentation

Control Instrumentation

Diagnosis, Adjustment, and Repair of Solar Energy Systems

Solar Energy Practicum

OTHER COURSES

Hydronic Systems

Analysis/Treatment of Water

Absorption Systems

Air Movement and Air Balancing

Hydraulic Components

Blueprint Reading and Specification

Estimating

Chemistry of Refrigerants

Measurements and Calibrations

Electromechanical Controls

Control of Heat Transfer Processes

SUMMARY AND RECOMMENDATIONS

The advisory committee's recommendation to the project coordinator and staff was that there exists an immediate need in industry for persons whose education, training and/or experience enable them to install, adjust, maintain, service, and repair solar heating and cooling systems. The extent of the need for trained manpower in this emerging industry is yet undefined.

In view of this conclusion, the advisory committee recommended that a market survey be conducted to determine the employement opportunities

in this field within the next five years.

The second recommendation was that a task analysis be conducted to determine the skills that are required for the development of a vocational education program and curricula for the training of solar energy technicians.

The final activity of the committee concentrated on the formulation of recommendations for a solar energy technology curriculum and vocational education program. The committee recommended that immediate steps be taken to design, plan, and implement a pilot curriculum in solar energy that would involve a multi-level approach. This should include a short-term intensive phase designed to upgrade present conventional HVAC techniques in the field of solar applications. It should also include a pre-employment, post-high school phase that would prepare technical competencies in two categories. The first category would concentrate on entry level skills such as installation and routine maintenance of solar energy systems. The second category would concentrate on diagnosis of problems and on making appropriate adjustments and repairs. This second category would involve up to two years of training.

It was the opinion of the committee that if the development of the curriculum progressed in stages, there would be a minimum risk for career obsolescence because the individual is simultaneously trained in conventional HVAC. The committee also acknowledged that emerging occupations, such as solar energy technology, offers new opportunities for the disadvantaged and the unemployed and underemployed.